ROOT AND SHOOT BIOMASS AND NUTRIENT COMPOSITION IN A WINTER RYE COVER CROP

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Root and shoot biomass and nutrient composition in a winter rye cover crop

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ABSTRACT

Nitrogen loss from applied fertilizer can be a significant environmental quality issue if NO_3 moves to surface or ground water. The Iowa nutrient reduction strategy science assessment identified winter cereal rye (*Secale cereal* L.) cover crop as a practice that can significantly reduce N and P loss (41% NO_3-N and 21% P reduction) from corn (*Zea mays* L.) and soybean [*Glycine max.* (L.) Merr.] fields. Cereal rye, when used as a cover crop, through its fibrous root system is able to explore the soil and use residual NO_3- N. In order to further understand the effectiveness of rye as a cover crop for scavenging and recycling N, there is a need to understand the amount of root/shoot biomass and N and carbon (C) partitioning between roots and shoots at the time of rye termination. This study was conducted at the Climate and Corn-Based Cropping Systems Coordinated Agricultural Project (CSCAP) cover crop site, located at the Ag. Engineering and Agronomy Research Farm, Iowa State University near Boone, IA. Corn was grown in rotation with soybean and winter cereal rye drilled following corn and soybean harvest (three N rates applied to corn, 0, 120, and 200 lb N/acre). Two ingrowth tubes per plot were installed between rye rows in fall of 2014 after rye seeding and the tubes were harvested the next spring at the time of rye termination. For rye following corn and soybean, shoot biomass, C, and N was significantly greater than in the root biomass, with about 30% of the total plant C and 15% of the total N in the root biomass. The C:N ratio of root material was consistently high (46-51 C:N), and at least double the shoot material (17-23 C:N). Therefore, N taken up by the rye was mainly partitioned to the shoot, and thus measurement of rye cover crop aboveground biomass provides the main N amount available for recycling from the rye cover crop. With the high C fraction and high C:N ratio of the root material, inorganic-N from the soil or degrading shoot material could be immobilized with root degradation.

INTRODUCTION

Cover crops are plants that are primarily integrated in the annual cropping system at times of the year when nothing is growing in the field. Due to many environmental benefits, cover crops have gained an increased interest in recent years (Iowa State University, 2014). Large scale leaching of soil NO_3-N from agricultural land to groundwater and river systems is a major environmental concern. Cover crops, with their extensive root system and potential to scavenge residual soil NO_3-N, are a possible solution (Sainju et al., 1998; Iowa State University, 2014). Apart from scavenging NO_3-N, cover crops also help control soil erosion and improve physical and chemical conditions through root growth and organic matter addition. Generally, belowground biomass of cover crops commonly comprise about 20-30% or more of its total plant biomass and can play a significant role in C and N dynamics of the soil (Puget and Drinkwater, 2001). Gardner and Sarrantonio (2012) emphasized that the contribution of cover crop roots to soil dynamics is poorly understood since there is little information available on its quantitative distribution.

Winter cereal rye, a commonly used cover crop in corn-soybean rotations in Midwest, is one of the most winter hardy adapted cover crops and can explore the soil through its fibrous root system. Cereal rye has an intense rooting near the soil surface (Bodner et al., 2010), and therefore living and decaying rye root systems and byproducts significantly contribute to the soil nutrient dynamics (Kavdir and Smucker, 2005). Limited information is available on the quantitative distribution of winter rye root biomass, including the relationship of root and shoot biomass in terms of C and N accumulation.

Studies on quality and quantity of root production and distribution are most common with certain row crops and tree species (Russell et al., 2004; Ontl et al., 2013). There is limited information available on rye cover crop root systems and nutrient accumulation/retention at time of termination. Since, winter rye as a cover crop is of current high interest in relation to NO_3 scavenging, surface water quality, and N recycling to annual crops, information is needed about the relation of the root system in regard to total plant biomass, C, and N. The objectives of this study were to quantify the root and shoot biomass production in a winter rye cover crop at the time of termination in spring and the partitioning of C and N between the root and shoot biomass.

MATERIALS AND METHODS

Site description

This study was conducted from the fall 2014 to spring 2015 at an ongoing CSCAP cover crop research site situated at the Iowa State University Agricultural Engineering and Agronomy Research farm near Boone, IA (42°00’34”N; 93°46’50”W). Soils were Clarion loam and Nicollet clay loam. The study consisted of a no till corn-soybean rotation (since 2008) with six N fertilizer rates (0, 120 and 200 lb/acre used for this study) applied to corn, with four replications (three replications used in this study for rye following corn) in a randomized complete block design and with winter cereal rye cover crop the main plot and N rate the subplot. Winter cereal rye (Wheeler variety) was no-till drilled (56 lb/acre in 7.5 inch row spacing) following corn (22 Oct. 2014) and soybean (30 Sept. 2014) harvest.

Ingrowth core method

Rye root growth was determined using a root ingrowth core technique (Russel et al.). In the rye following corn and soybean, plots receiving 0, 120, and 200 lb N/acre (applied to corn) had two ingrowth tubes installed (0-24 and 0-12 inch depth following corn and soybean, respectively) between the rye rows shortly after seeding. The tubes were collected the next spring at rye termination (following soybean 29 Apr. 2015 and following corn 8 May 2015).

Ingrowth tubes were polypropylene tubing, 2.2 inch diameter with 0.03 sq. inch mesh opening. The bottom of the tube was sewn with a screen with 0.02 sq. inch mesh size. For installation of the ingrowth tubes, soil cores (depth and diameter similar to ingrowth tube) were collected between rye rows with a hand-operated soil corer. Soil per each depth was sieved and cleaned of any roots and plant debris, and placed in the tubes, and compacted approximately to its original bulk density. The ingrowth tubes were installed in the cored holes from where soil was collected. Ingrowth tubes were removed the next spring at the time of rye termination and stored at 4°C for no more than 7 days while processing to separate root biomass from soil (Ontl et al., 2013). Sections of soil from the ingrowth tubes were washed in a root elutriator with a 250 μm mess screen. Roots were hand sorted from the debris and dried at 65°C (Russell et al., 2004). The dried roots were weighed and ground in a ball mill before analyzing for total C and N by dry combustion.

Soil NO_3-N samples (composite of three cores, 0-12 inch depth) were collected around the ingrowth tube locations at the time of ingrowth tube installation and removal. For the estimation of rye aboveground biomass, rye shoots were collected within a 1 sq. ft. frame centered on each side of the ingrowth tube encompassing the two rye rows. Shoot material dry matter was determined after drying at 65°C. Root and shoot dry matter mass, C, and N were calculated as the equivalent area represented by the ingrowth tube.

RESULTS AND DISCUSSION

The N fertilizer rate applied to the prior corn crop did not have any effect on soil NO_3-N concentration in the top foot of soil (Table 1), and therefore did not influence the rye cover crop root and shoot biomass, C, and N ($P \leq 0.05$) following corn or soybean (Tables 2-3). The residual soil NO_3-N concentration was low at both the time of ingrowth tube installation and in the spring at time of tube removal (time of rye termination). The low concentrations are a reflection of the high crop yields (data not shown) and overall wet conditions at the site for the preceding year. Interestingly, the concentrations increased slightly from the fall to spring following corn, despite the rye growth. And, for following soybean, the concentrations did not decrease with the rye cover crop.

The rye biomass, C, and N amounts (mean across N rates applied to corn) were greater in the shoot than root with the rye following both corn and soybean (Tables 2 and 3). For example, 22 and 32 lb N/acre in the shoot material (following soybean and corn, respectively), and only 5 and 4 lb N/acre for the respective root material. The ratio of rye shoot:root biomass and C were similar, as would be expected, but were considerably narrower than for N (Table 4). The shoot:root biomass and C ratio was 2.2-2.8, but 6.0-6.1 for N, indicating considerably more of the rye plant N was in the shoot material. Of the rye plant biomass and C, 27-28% was in the roots following corn and 29-31% following soybean. But for plant N, only 15% was in the roots following corn and 14% following soybean (corresponding 85 and 86% of N in aboveground rye material). The distribution of C and N between root and shoot material affected the C:N ratio (Table 5), which was more than double for root (46 to 51 C:N ratio) than shoot material (17-23 C:N ratio). These root C:N ratios would have an effect on potential mineralization or use of soil derived N for microbial rye material degradation and release (recycling) of plant-available N.

SUMMARY

The shoot biomass of the rye cover crop was more than twice the amount of root biomass. Although rye roots comprised approximately 30% of the plant C, there was only approximately 15% of plant N in the roots. The largest fraction of total N uptake and C assimilation by the rye cover crop was contained in the aboveground biomass. With the low root N amount, the C:N ratio of root material was high enough to likely cause N immobilization during degradation of the roots. Since N taken up by the rye was mainly partitioned to the shoot material, measurement of rye cover crop aboveground biomass provides the main N amount available for recycling from the rye cover crop and main amount for estimation of rye cover crop N uptake. With the high C fraction and C:N ratio of the root material, N from the soil or degrading shoot material could be immobilized during root degradation and thus reduce the potential for recycling plant-available N to the annual crop.

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Table 1. Soil NO_3-N (0-12 inch depth) at the location of the ingrowth tubes in the fall and spring at time of rye termination, by N rate applied to corn.

	Following corn		Following soybean	
N rate	Fall	Spring	Fall	Spring
lb/acre	---------------------- ppm		---------------------	
0	1.9	2.6	5.3	4.9
120	0.6	1.8	1.8	3.2
200	1.8	2.2	4.2	4.9
Mean	1.4b	2.2a	3.8a	4.3a

Mean within a crop with different letter is significantly different, $P \leq 0.05$.

Table 2. Rye cover crop plant components at time of in-growth tube removal, following corn.

	Biomass			Carbon			Nitrogen		
N rate	Shoot	Root	Mean	Shoot	Root	Mean	Shoot	Root	Mean
lb/acre	----------	----------	----------	----------	lb/acre	----------	----------	----------	----------
0	1096	485	790	443	204	324	19	4	12
120	1287	464	875	518	195	357	23	4	13
200	1301	438	869	529	184	357	23	4	13
Mean	1228a	462b		497a	194b		22a	4b	

Only main effect of plant component significantly different, $P \leq 0.05$.

Table 3. Rye cover crop plant components at time of in-growth tube removal, following soybean.

	Biomass			Carbon			Nitrogen		
N rate	Shoot	Root	Mean	Shoot	Root	Mean	Shoot	Root	Mean
lb/acre	----------	----------	----------	----------	lb/acre	----------	----------	----------	----------
0	1349	575	962	538	246	392	30	5	18
120	1413	636	1024	567	284	426	32	5	19
200	1359	501	931	553	222	387	34	5	20
Mean	1374a	571b		552a	251b		32a	5b	

Only main effect of plant component significantly different, $P \leq 0.05$.

Table 4. Rye cover crop plant shoot:root ratio.

	Following corn			Following soybean		
N rate	Biomass	Carbon	Nitrogen	Biomass	Carbon	Nitrogen
lb/acre						
0	2.6	2.5	5.6	2.3	2.2	5.9
120	2.8	2.7	6.6	2.2	2.0	5.6
200	3.1	3.0	6.2	2.7	2.6	6.3
Mean	2.8	2.7	6.1	2.4	2.2	6.0

No statistical difference due to N rate, $P \leq 0.05$.

Table 5. Rye cover crop plant components C:N ratio.

	Following corn		Following soybean	
N rate	Root	Shoot	Root	Shoot
lb/acre				
0	52	23	49	17
120	53	22	50	18
200	47	23	41	15
Mean	51a	23b	46a	17b

Only main effect of plant component significantly different, $P \leq 0.05$.